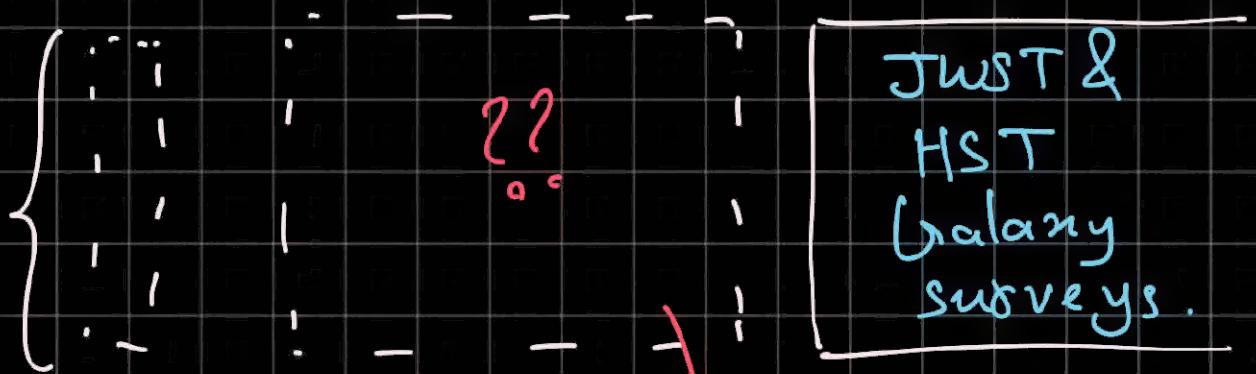


# New approaches in Modelling & interpretation of the Cosmic Dawn 21cm

- Introduced Cosmic Timeline  
→ 14 bil yrs.  $\sim$  Cosmic Dawn
- Introduced CMBR a bit.
- Plank emission



- Expansion const.

★ 21cm is the probe for this period.

Why 21cm?

→ Probe of thermal history

→ Star & galn. formation history

→ Galaxy spectra, e.g. X-ray spectral energy dist.

→ Fundamental nature of dark matter

→ Signature of non-standard cosmology at high redshift.

### 21cm - Exps.

① EDGES → Bowman 2018

② SARAS → Singh 2022

③ REACH

↪ South Africa

$28 > z > 7.5$

★ Spin-flip 21cm : Physics of 21cm line

↪ Hyperfine splitting.

$$\frac{n_1}{n_0} = 3 \exp\left(\frac{-h\nu_{hf}}{kT}\right)$$

$n_0$

$1 / (K_B T_s)$

Two processes affect spin temperature

(1) First. processes by CMB photon

$$T_s \rightarrow T_{\text{CMB}}$$

(2) Indirectly by Lyman- $\alpha$  photons

$$T_s \rightarrow T_K$$

$$\Rightarrow T_s = T_s(T_{\text{CMB}}, T_K)$$

Encapsulates details of astrophysical

$\Rightarrow$  Differential brightness :

$$\begin{array}{c} \textcircled{T_{\text{CMB}}} \\ B_g \end{array}$$



$$\textcircled{T_s}$$

21cm brightness  
of the intervening  
cloud

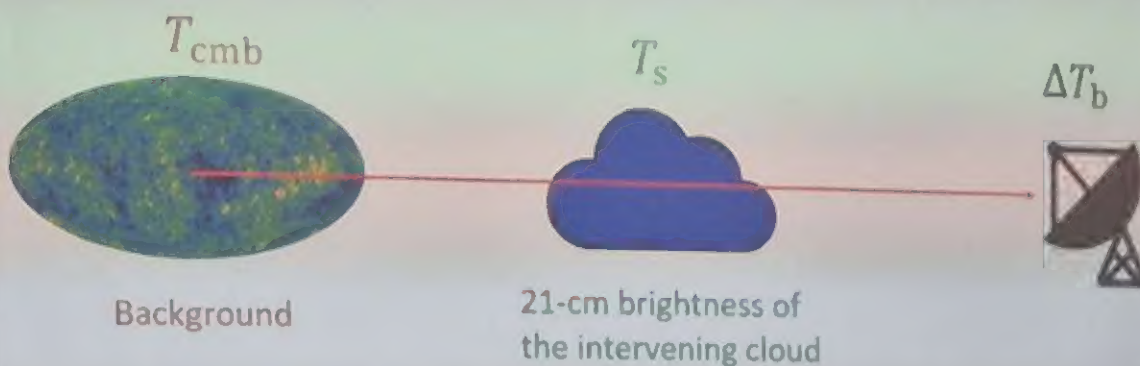


$$\frac{\Delta T_b}{T_b}$$

Global Signal:



Our observable is a differential brightness



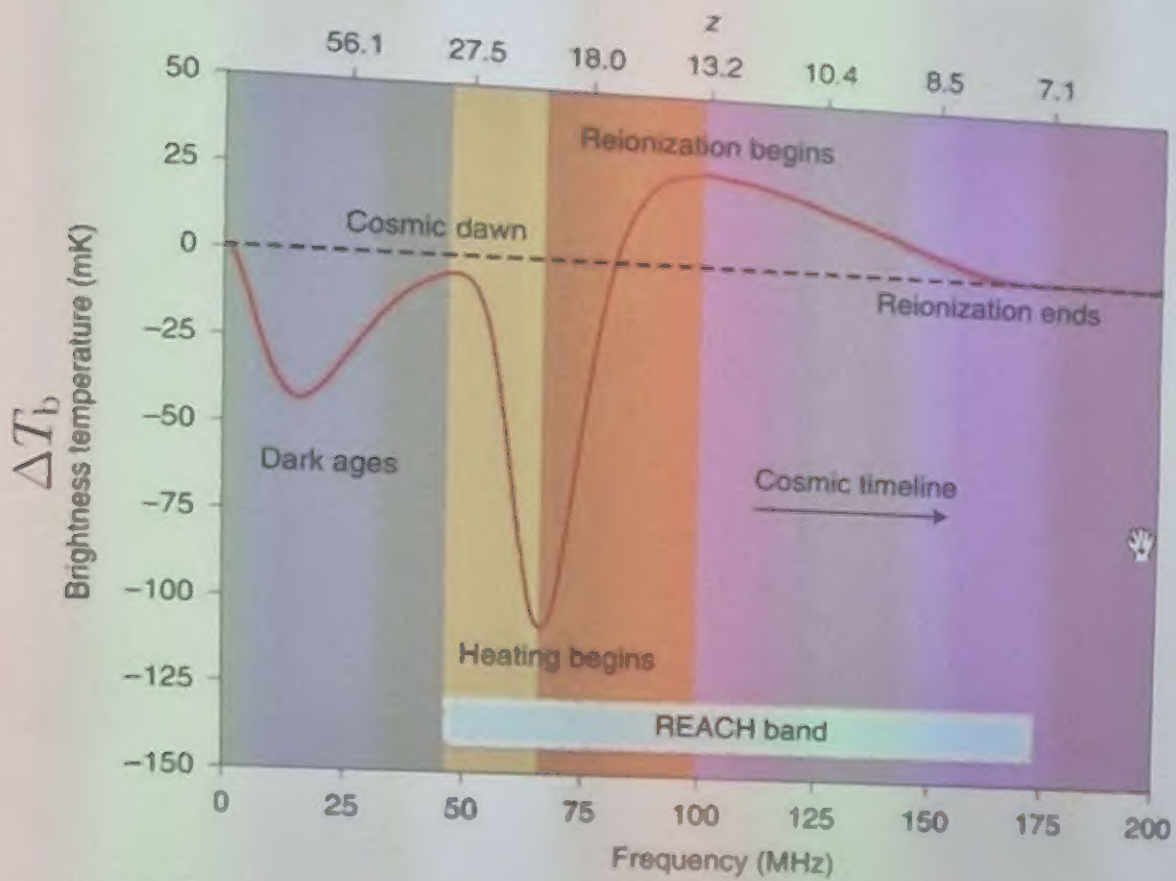
For radio intensities it is convenient to work in terms of temperature

$$\Delta T_b = 27 x_{\text{HI}} \left( \frac{1 - Y_p}{0.76} \right) \left( \frac{\Omega_B h^2}{0.023} \right) \sqrt{\frac{0.15}{\Omega_m h^2} \frac{1+z}{10}} \left( 1 - \frac{T_{\text{cmb}}}{T_s} \right) \text{ mK}$$

Shantanu Mittal

Madau et al. (1997), Furlanetto (2002)

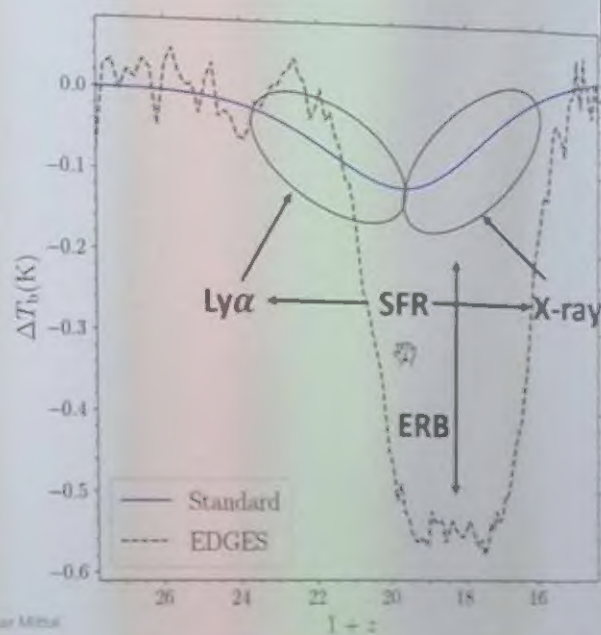
# A standard model for the global 21-cm signal





## A strong absorption feature in the 21-cm measurement by EDGES

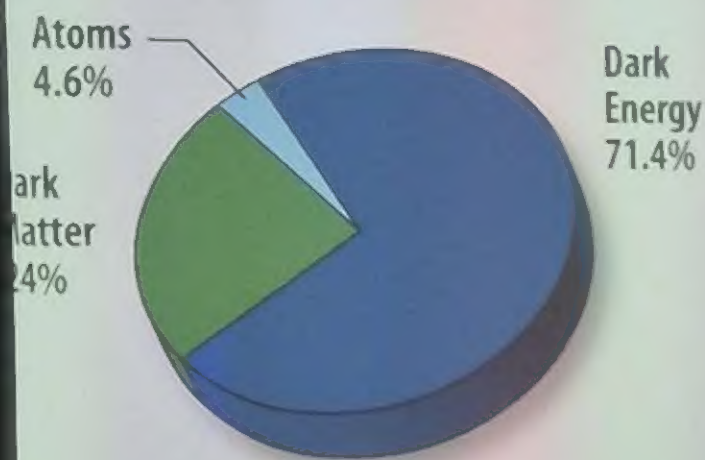
- A standard 21-cm model is described by  $\sim 4$  parameters
- Given some data, we can constrain these parameters



EDGES: Experiment to Detect the Global Epoch of Reionization Signal (Bowman et al. 2018)

Shubham Mittal

# Primordial black holes are interesting dark matter candidates



## Possible candidates

- WIMP
- Axion
- **Primordial black holes**
- ...

Shikhar Mittal



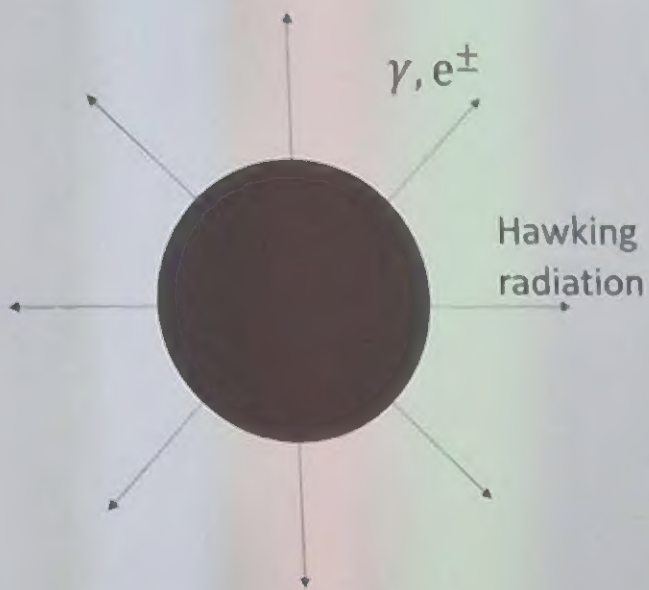
# What are primordial black holes?

- Compact objects that formed in an early Universe
- Gravitational collapse of over-dense regions
- We want to put constraints on its abundance

$$f_{\text{PBH}} = \frac{\rho_{\text{PBH}}}{\rho_{\text{DM}}}$$



# PBHs heat the intergalactic medium



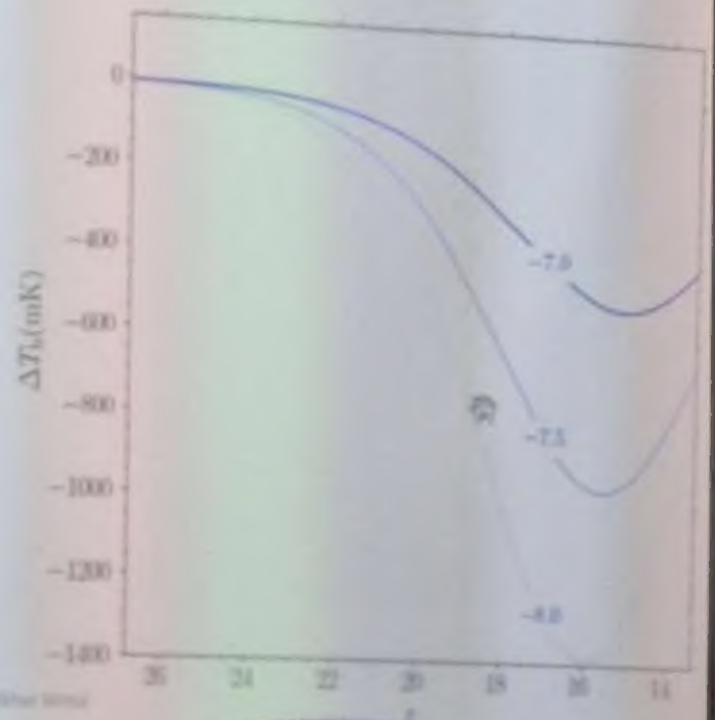
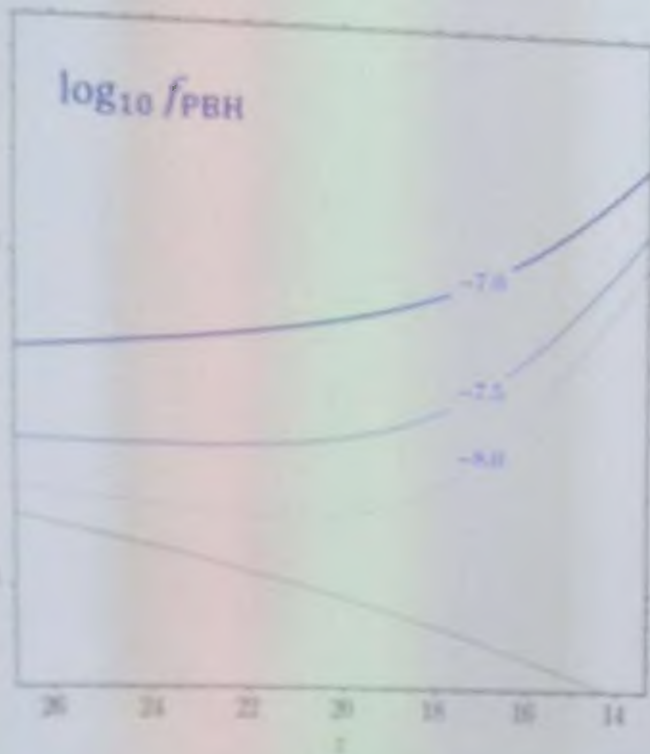
$$T_k \rightarrow \Delta T_b$$



$T_k$  - gas temperature

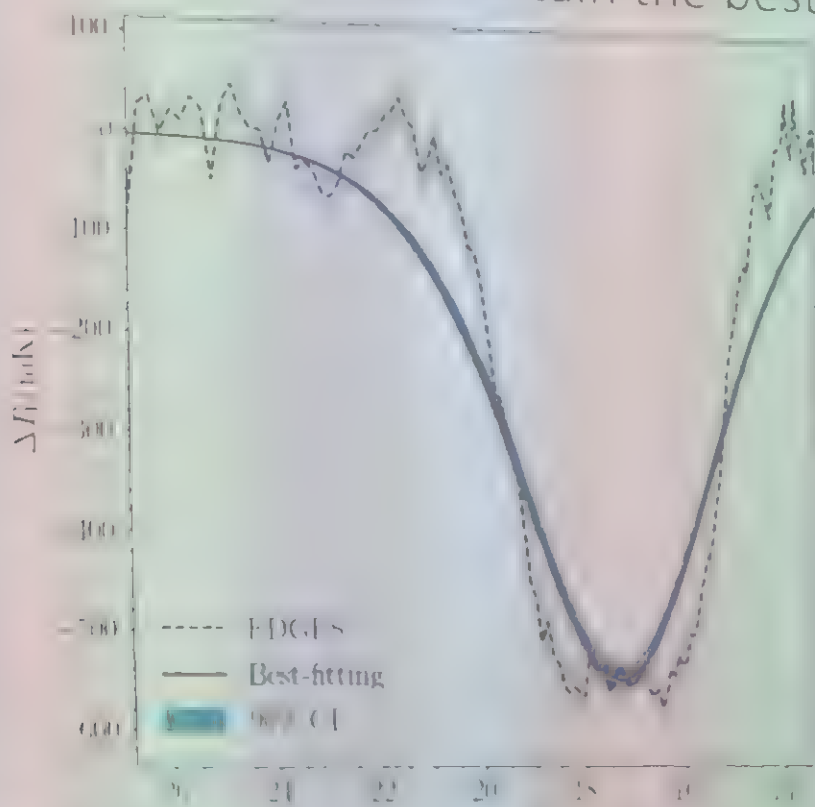
IGM = Intergalactic medium

## PBH heating affects 21-cm signal



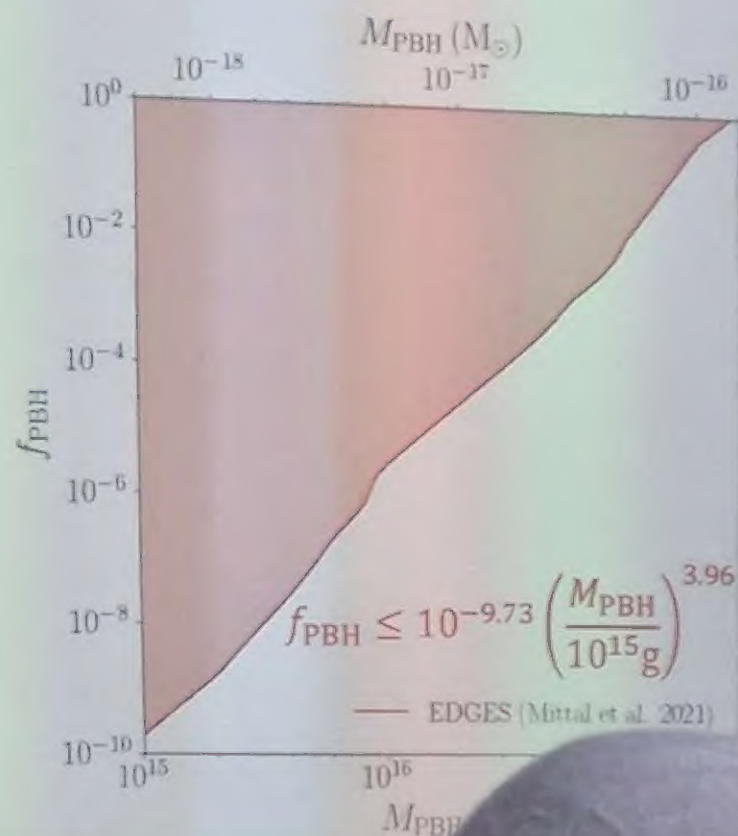


Using Bayesian inference we obtain the best-fitting model



$$M_{\text{PBH}} = 10^{15}$$
$$f_{\text{PBH}} \leq 10^{-9}$$

Repeating the analysis for a range of masses we obtain our constraints

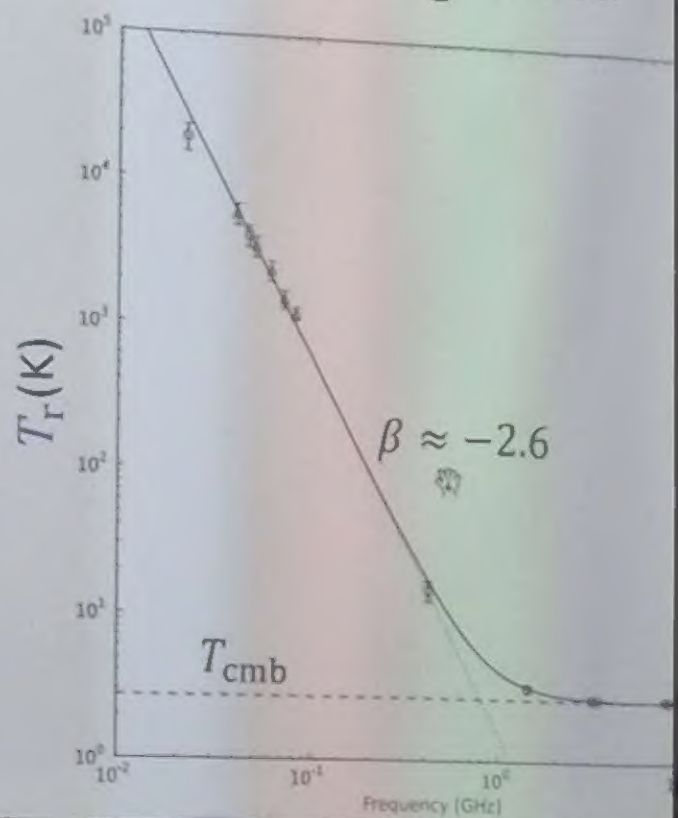


Mittal et al. (2021)



# Understanding the excess radio background

- *ARCADE2* observed a non-thermal low-frequency sky spectrum in 2011
- Later independently confirmed by *LWA1* in 2018

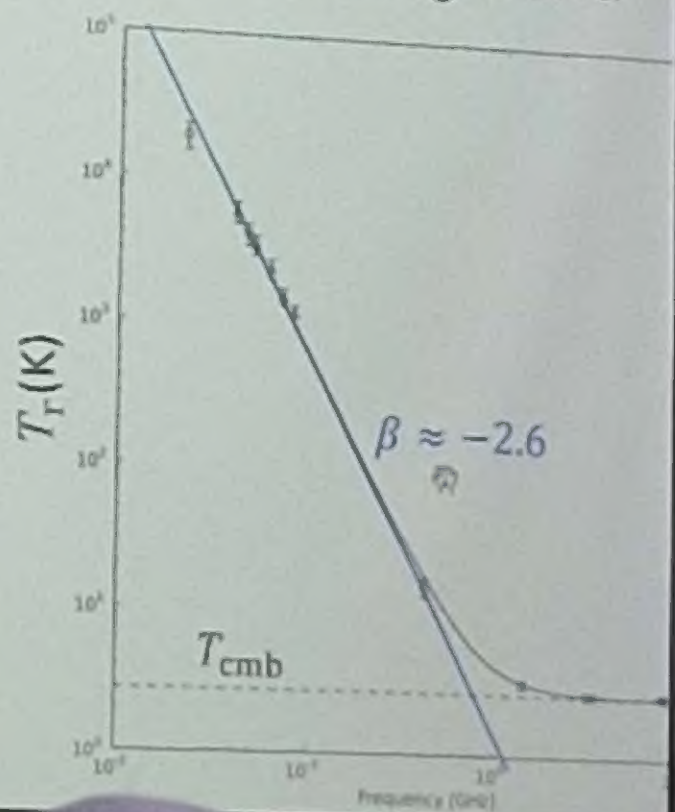


en et al (2011), Dowell & Taylor (2018)



# Understanding the excess radio background

- ARCADE2 observed a non-thermal low-frequency sky spectrum in 2011
- Later independently confirmed by LWA1 in 2018
- $T_r = T_{\text{cmb}} + T_{\text{ERB}}$
- The origin of this radio background is unknown



en et al (2011), Dowell & Taylor (2018)



-cm observation provides an independent confirmation of ERB

Additional radio background  
leads to a stronger contrast  
and hence the signal

$$\Delta T_b \propto \left(1 - \frac{T_r}{T_s}\right)$$

